RESEARCH

Women empowerment, Land Tenure and Property Rights, and household food security among smallholders in Nigeria

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Abstract

Background: Empowering women, land tilting to enhance the security of Land Tenure and Property Rights (LTPRs) in agriculture *vis-a-vis* food and nutrition security are crucial in the pursuit of the Sustainable Development Goals. The main goal of this paper is to examine the crucial roles of women's empowerment and LTPRs as they affect household food security among smallholder farmers in Nigeria.

Methodology: Cross-sectional data were obtained from 1152 maize and rice farmers, selected by multistage random sampling across 192 communities, 16 States and the six geopolitical zones in Nigeria. The data were collected on households' socio-economics, food security situations, empowerment and LTPRs on parcels cultivated during the 2016/17 farming season by interviewing the adult members of the farmers' households. HFS was assessed using the United States Department of Agriculture' HFS Survey Module and Food and Agriculture Organization guidelines for measuring Household Dietary Diversity Score. LTPRs were measured in terms of tenure type and title registration to farmlands. HFS modelling was within the framework of Poisson, Instrumental Variable Poisson (IVP) and Zero-inflated Poisson (ZIP) regression methods, with endogeneity concerns and choice of specification addressed within Hausman specification tests.

Results: The results of the study show that households that have a share of farmland on purchase and also participate in off-farm activities are likely to be certainly food-secure in all regards. Crop diversity, households that cultivate maize only, the share of farmland on purchase and access to extension contact significantly reduce the severity of food insecurity while an increase in farm size increases the severity of food insecurity. Similarly, IV Poisson and ZIP Count results show that increase in the farm size results in the severity of food insecurity. The evidence with respect to women's empowerment reveals that gender parity and female achievement in group membership, income control, as well as workload; reduce the extent of food insecurity among the farming households in Nigeria. We, however, discover that the female achievement in the productive decision and credit increases the severity of food insecurity among the smallholder farmers. The analyses also reveal that education of the household head, female achievement in the asset; group membership and workload are the major factors that positively influenced household dietary diversity.

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Conclusion: The study suggests the adoption of climate-smart practices to overcome the issue of marginal farmlands, promotion of crop and livelihood diversification among the smallholder farmers, effective extension services delivery, and improving women's access to productive resources to enhance household food security status in Nigeria.

Keywords: Women's empowerment, Land Tenure and Property Rights, Household food security, Smallholders, Nigeria

Background

Empowering women, land tilting to enhance the security of Land Tenure and Property Rights (LTPRs) in agriculture *vis-a-vis* food and nutrition security are crucial in the pursuit of the Sustainable Development Goals (SDGs) 2 and 5 which are to be achieved by the year 2030. These SDGs emphasized the need to end hunger, achieve food security, improve nutrition and promote sustainable agriculture as well as to achieve gender equality, and empower all women and girls. Women's empowerment includes equal access to and control over household income and productive resources, reduced time constraints, and joint decision-making with respect to labour and household expenditures [7, 13].

LTPRs have to do with the rights that individuals, communities, families, firms and other community structures hold in land and associated natural resources. As noted by Feder and Feeny [25], the rights on the land are either de facto or *de jure* secure if they are clearly defined, exclusive, enforceable, transferable, and also recognized by relevant authorities. In Nigeria, the law made provision for granting two types of land use rights—*customary and statutory rights of occupancy*—to all categories of land users [35]. Customary right of occupancy is granted under the Act by the local government councils to individuals, firms, and communities while the Statutory right of occupancy is the right to use land in any part of the state and it is granted under the Act by the State Governor. A certificate of occupancy is issued to a land user as evidence of being granted statutory right of occupancy on the land by the State Governor, thus making the certificate of occupancy the highest form of land title in Nigeria. Issuance of certificate of occupancy requires that the landowner possesses a purchase receipt, duly stamped deed of transfer, and an approved boundary survey of the land. The customary rights of occupancy are governed by the largely unwritten customary laws in various localities and are also considered de facto held by holders of agricultural lands in rural areas that have been under use for agricultural purposes prior to the enactment of the Land Use Act of 1979 [35, 52].

The underlying principle behind the consideration of women's empowerment in agriculture as a determinant factor of household food security is in its essentiality to achieve food security and reducing hunger as well as improve household agricultural productivity [23, 36]. Women's empowerment and secure LTPRs can be linked to household food security in multiple pathways. First, they can directly contribute to the agricultural production of the smallholders. Second, agricultural productivity gain can improve farm income, and income gain can, in turn, result in physical and economic access to food which eventually improves the food and nutrition security of the farmers.

Access to land, the security of tenure and women's empowerment are the main means through which food security can be realized in Africa, Nigeria inclusive [8, 29, 56]. Hence, they remain at the centre of agricultural research and outreach practices in developing countries because they have a direct impact on agricultural productivity and household food security. A large proportion of the smallholders, particularly female farmers, however, lack adequate access to quality land, and when they do have access, they have limited rights to it [4, 48] as they might be able to cultivate the land but not being able to use it as collateral, rent it, sell it, or hold the land for a long enough period to recoup labour and capital investments.

Women produce over 50 percent of the world's food [23, 26] and comprise about 43% of the agricultural labor force in addition to their traditional domestic responsibilities, both globally and in developing countries [14]. This agrees with the findings of Palacios-Lopez et al. [45] who found the share of female labour to be a little above 50% in Malawi, Tanzania and Uganda and significantly lower in Nigeria (37%). Though women earn and produce much less than men, they still invest as much as ten times more of their earnings than men do in their family's well-being, in areas including child health, education, and nutrition [18]. While there is a paucity of data and statistics on women's share of food production in Nigeria as of date, Akingbule [5] estimated that women produced about 80% of food in Africa despite their inadequate access to productive resources.

Considering women's important role in the agricultural sector, empirical evidence shows that there is a gender gap with respect to access to productive resources, such as land and livestock, labour markets, financial capital,

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education, technology, and advisory services, as against their men counterparts [2, 16, 32, 63]. Women are generally prone to landholding inequality and tenure insecurity in sub-Saharan Africa [24, 43]. Existing research suggests that cultural norms and values restrict women's ability to inherit the land [37], therefore, making women farmers be more vulnerable to climate impacts than men because they greatly depend on natural resources for livelihoods and food security [46, 60]. It is important to note that the gender gap negatively affects women's productivity as well as their contribution to the agricultural sector and the achievement of bigger economic and social development goals [23].

Several empirical studies have found that redistributing inputs between men and women in the household has the potential to increase productivity [34, 47]. In Bangladesh, women's empowerment was found to increase per adult-equivalent calorie availability and dietary diversity [55]. In the same vein, Doss [15] confirms that in Ghana, women's share of assets with respect to farmland increased significantly the food expenditure budget. Duflo and Udry [19] and Hoddinott and Haddad [31], on the other hand, found that in Côte d'Ivoire, the more the women's share of cash income increased significantly the share of household budget allocated to food.

Arising from the foregoing, using smallholder maize and rice farmers in Nigeria as a case study, this paper examined the effects of women's empowerment in agriculture and LTPRs on household food security (HFS). We measure the HFS using the United States Department of Agriculture's (USDA's)—18 questions HFS modules (Table 10) as well as the Food and Agriculture Organization of the United Nations (FAO) guidelines for measuring Household Dietary Diversity Score (HDDS).

The paper contributes to the ongoing debates on women's empowerment, LTPRs and HFS in Africa's smallholder agriculture in a number of ways. First, it updates empirical evidence on the forms of LTPRs that operate for agricultural lands in Nigeria. Second, it measures women empowerment using the abbreviated version of the Women's Empowerment in Agriculture Index (WEAI) [9]. Third, it provides empirical evidence on the effect of gender parity and the achievement in each of the five domains of empowerment on HFS will be among the smallholders in Nigeria. Fourth, it provides empirical evidence on how empowering women, tenure types and titling as well as other control variables, affect HFS among smallholder maize and rice farmers in Nigeria. The analyses were within the framework of Poisson, Instrumental Variable Poisson (IVP) and Zero-inflated Poisson (ZIP) regression methods, with endogeneity concerns as well as the choice of specification addressed within the framework of Hausman [30] specification test.

The approach supported the provision of answers to five pertinent research questions, including:

1. Which of the hypothesized determinants are most likely to guarantee that a farm household will achieve a household food security score of zero?
2. Which of the hypothesized determinants contributes to the severity of food insecurity among households of the maize and rice farmers?
3. To what extent do the significant variables contribute to the severity of food insecurity among households of the maize and rice farmers?
4. Which one of LTPRs, gender parity and the achievement in each of the five domains of empowerment influence the household dietary diversity score of the maize and rice smallholders in Nigeria? and
5. To what extent do LTPRs, gender parity and the achievement in each of the five domains of empowerment influence the household dietary diversity score of the maize and rice smallholders in Nigeria?

Even though some empirical studies focused their attention on the effect of women's empowerment on food security and nutrition outcomes, such as body mass index, stunting, underweight and wasting [6, 51, 53, 54], it was generally found that women's empowerment has the potential to improve both outcomes. So far, only three of those empirical studies [4, 13, 56] used the Abbreviated WEAI to measure women's empowerment and thereafter determine the effects of women's empowerment on food security and agricultural productivity. It is pertinent, however, to note that all the above-mentioned empirical studies were done outside Nigeria. The only exception is Tanankem et al. [58] who used modified Alkire et al. [9] to assess women empowerment in their work titled "women empowerment and intra-household dietary diversity in Nigeria". This study, therefore, attempts to fill these identified gaps.

The next section provides the literature review on HFS in Nigeria. The third section presents the research methodology, including the method of data analysis and analytical methods. The fourth presents results and discussion, while the final section presents the conclusions and policy implications.

Literature review on household food security in Nigeria

Food security in terms of physical and economic access to sufficient food to meet dietary needs has been a serious problem in Africa, Nigeria inclusive. Evidence from recent studies that were carried out on dietary diversity in Nigeria [11, 40, 58] used the Living Standards Measurement Study—Integrated Surveys on Agriculture

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(LSMS-ISA) 2003/2004, 2010/2011, 2012/2013, and 2015/2016 dataset of the World Bank. These studies emphasized the extent of food consumption diversity and the factors influencing demand for diverse foods, household dietary diversity among low-income urban households, the relationship between production diversity and dietary diversity and the linkages between empowerment and the dietary diversity of households. The household dietary diversity was measured using the count of 12 food groups based on the 7-day recall household food consumption data in the LSMS-ISA survey.

Obayelu and Osho [40] employed the Simpson index to determine how diversified the diet of low-income urban households in Nigeria is. Simpson's value varies from zero to one, the higher the Simpson value, and the greater the variety. The index was later classified into low and very low dietary diversity. Ayenew et al. [11] used unbalanced panel data to analyse the relationship between production diversity and dietary diversity in Nigeria. Information on the household dietary diversity was collected twice—at the post-harvest and post-planting—and this makes it possible to evaluate the seasonality of dietary diversity of the household. Obayelu et al. [41], on the other hand, grouped the various food consumed by the households into 12 categories which were later coded and summed into HDDS. They categorized the HDDS which ranged 0–12 food groups into low (≤ 6) and high (6–12) dietary diversity. Households with high HDDS are classified as food-secure while those with low HDDS are classified as food insecure.

Evidence from Onyeji and Sanusi [44] assessed the nutritional status of the reproductive age women with the use of anthropometric indices, weight, and height to estimate the Body Mass Index (BMI), and they eventually checked if there was a correlation between the individual dietary diversity score (IDDS) and BMI of the respondents. Thus far, Tanankem et al. [58] seem to be the only study that investigated the relationship between women's empowerment and the dietary diversity of households in Nigeria using LSMS-ISA data. They measured women empowerment using modified Alkire et al. [9] measure of Women Empowerment in Agriculture Index. WEAI assesses empowerment based on five domains—decisions about agricultural production, access to and control over productive resources; control of the use of income; leadership in the community; and time allocation while they constructed modified WEAI using another five domains which are: access to and control over productive resources, leadership in the community, education, information and connection, as well as insurance.

Most previous household dietary diversity studies in Nigeria modelled HDDS within the framework of probit, instrumental variable (IV) probit, non-parametric regressions that are based on the local polynomial regression approach, traditional least square regression, random and fixed-effect model. Empirical evidence shows that most of these studies did not test for endogeneity with the exemption of Obayelu et al. [41] who corrected for endogeneity between human capital and food insecurity status among households in rural Nigeria within the framework of Instrumental Variable (IV) probit. They, however, found that there was no bi-causality between human capital and food insecurity. Tanankem et al. [58] also identified that the empowerment variable is likely to be prone to endogeneity. Hence, they applied the standard instrumental variable technique to correct for possible endogeneity bias and used the age difference between the primary male and female decision-makers as well as the type of building in which the household currently resides as the instruments.
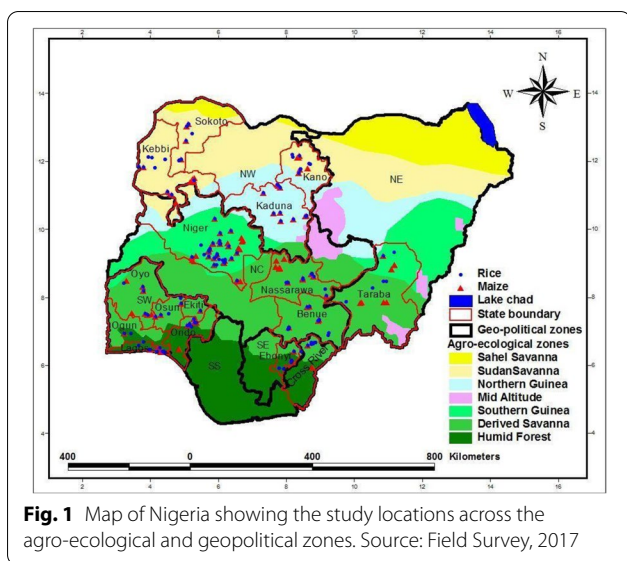
Ayenew et al. [11] found that in the post-harvest season, an increase in farm production diversification is associated with an increase in dietary diversity. However, production diversification does not have a significant contribution to dietary diversity in the post-planting season. Tanankem et al. [58] found that increases in women's empowerment are positively associated with household dietary diversity. Evidence from Ogundari [42] showed that the probability of a household falling into any of the food insecurity categories as against being food-secure decreases significantly and consistently with income, household size, whether households consumed only purchased food, and the geographical region of the household. This probability, however, increased if the household consumed only home-produced food. Dietary diversity was also found to increase with household income and household size, whether the household head was a farmer, whether households consumed only purchased food, and whether households resided in the rural areas. He, however, found that educated household heads and those consuming only home-produced food consumed a less diverse diet.

In conclusion, there is a paucity of empirical studies on how women empowerment and LTPRs contribute to HFS in Nigeria. Though, there are several empirical studies done outside Nigeria where WEAI was used to examine the impact of women's empowerment on food and nutrition-related outcomes. These among others are the gaps this study seeks to fill.

Research methodology
Description of the study area
The study was conducted in selected farming communities reputed for maize and rice production across the six geopolitical zones, and covering five of the seven Agro-ecological zones (AEZs) of Nigeria Fig. 1. Nigeria is

Fig. 1 Map of Nigeria showing the study locations across the agro-ecological and geopolitical zones. Source: Field Survey, 2017

situated in the West African region and lies between longitudes 3° and 14° and latitudes 4° and 14°. It has a landmass of 923,768 sq. km. Nigeria shares a land border with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast. Administratively, it is made of 36 States and the Federal Capital Territory. The States are commonly grouped into six geopolitical zones: Southeast, Southwest South-south, Northeast, Northwest, and North central geopolitical zones.

The study design
The study was part of the FUNAAB-RAAF-PASANAO project implemented by the Federal University of Agriculture, Abeokuta (FUNAAB) in partnership with the National Cereals Research Institute, Baddegi, and funded by the Economic Community of West African States. The central focus was on Incentivising Adoption of Climate-Smart Agricultural Practices in Cereals Production in Nigeria. The data were collected in a Nationwide Farm Household Survey conducted across the six geopolitical zones in Nigeria, focusing on maize and rice farmers. The respondents were selected in a three-stage sampling process, described as follows:

Stage I: Purposive selection of 16 States Fig. 1 that have been the leading rice and/or maize producers in Nigeria, based on production statistics from National Bureau of Statistics (NBS) [39].
Stage II: Purposive selection of three Agricultural Blocks per State per crop from the main rice and maize producing areas of the State, and two Exten-

sion Cells per block—that is, six blocks per state, 12 Cells per State and 192 Cells in all.
Stage III: Proportionate stratified random selection of six Rice and maize farmers from members of rice/maize farmers' association in each of the selected cells.

This process yielded 1152 households of rice farmers, from which a complete dataset was collected through personal interviews of the farmer and other farming members of their households. Data were collected on a wide range of issues, including the households' socio-economics, women empowerment, food security and LTPRs on parcels cultivated during the 2016/17 farming season.

Method of data analysis
To analyse the data, descriptive statistics, United States Department of Agriculture's (USDA) Approach—18 questions household food security modules, household dietary diversity score guideline, Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) and econometric models (Poisson, Zero-Inflated Poisson and Instrumental Variable Poisson) were applied. The detailed descriptions of how each variable is measured are provided below.

Measurement of household food security
The main outcome variable for this study is Household's Food Security (HFS) while women empowerment, LTPRs and a number of socio-economic predictors of HFS were the explanatory variables. HFS was measured using the USDA's—18 questions household food security modules (Table 10), as well as, the Food and Agriculture Organization of the United Nations (FAO) guidelines for measuring Household Dietary Diversity.

USDA approach—18 questions household food security modules
This approach has the advantage of having been tested, validated and consistently used by USDA in HFS monitoring in the USA, over the years. It is particularly suitable for capturing both the incidence and severity of food insecurity and adaptable to many climes. The experiences of the 18 questions seek to elicit are such that households can easily recall over a period of up to 12 months than actual expenditure. It thus tends to be a much more reliable measure of food security in settings, such as Nigeria, where most households do not keep records of their consumption.

There are three items in the USDA HFS survey modules that ask about experiences of the entire household. Seven items ask about experiences and behaviour of the adult

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members of the household, and eight items ask about experiences and conditions of the children in the household. An affirmative response to each of these questions is score one (1) while households that did not experience each of the food insecurity situations are scored zero (0). The scores are summed up across all questions to determine HFS Scores of a household. This could add up to a maximum of 18 for households with at least a child and maximum of 10 for households without children. Table 11 shows how households may be categorised into four mutually exclusive HFS categories based on the HFS Scores, following USDA [59]. The categories include high food security, marginal food security, low food security, and very low food security.

Household dietary diversity score guideline

The Household Dietary Diversity Score is a guideline developed by the Food and Agriculture Organization of the United Nations and it captures the quantity and, to an extent, quality of household food consumption [22, 57]. HDDS is meant to provide in summary the degree of household economic access to consume a wide range of foods. According to FAO guideline, the dietary diversity scores were created by counting the food groups consumed by a household over a certain period of time usually ranges from one to three days, but seven days and periods of up to 15 days have also been reported in the literature [17, 50]. This study makes use of seven days' recall data collected from the surveyed household and the following set of 12 food groups is used to calculate the HDDS: Cereals, White tubers and roots, Vegetables,[1] Fruits,[2] Meat,[3] Eggs, Fish and other seafood, Legumes, nuts and seeds, Milk and milk products, Oils and fats, Sweets, and Miscellaneous (Spices, condiments and beverages). We collected data for the HDDS[4] indicator by asking the respondent[5] a series of yes or no questions with respect to the food groups consumed by the household members in the home or prepared in the home for consumption by household members outside the home during the last seven days. For a "YES" response, one point is awarded, otherwise, zero point was awarded.

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[1] The vegetable food group is a combination of vitamin A rich vegetables and tubers, dark green leafy vegetables and other vegetables.

[2] The fruit group is a combination of vitamin A rich fruits and other fruits.

[3] The meat group is a combination of organ meat and flesh meat.

[4] One of the reviewers suggested the need to do a Wilcoxon test to test the null hypothesis that both outcomes (USDA HFS scores and HDDS) have the same distribution with the same median. We wish to note, however, that the Z statistics in Wilcoxon test is -11.650 at $p < 0.01$, thus indicating that USDA HFS scores and HDDS are statistically different from one another and hence, the need to run the two analyses.

[5] This is the person responsible for food preparation in the household in the last 7 days.

Values for the dietary diversity variable were later computed by adding all the 12 food groups included in the dietary diversity score for each household, therefore, making all scores to be within the range of 0–12.

Measurement of women's empowerment

Women's empowerment is one of the key regressors in this study together with LTPRs and other control variables. The aim is to establish the linkage between women's empowerment and the outcome variable—HFS scores and HDDS. In this study, women's empowerment is measured using the A-WEAI, which is an abbreviated version of the original Women's Empowerment in Agriculture Index. A-WEAI was developed as an improvement over WEAI based on the response obtained from the survey *vis-a-vis* the time it takes to complete the WEAI questionnaire and the inability to comprehend some of the subsections [36]. The original WEAI is computed using ten indicators while the A-WEAI makes use of only six indicators. The A-WEAI just like its antecedent measures women's empowerment in their roles and extent of engagement across five agricultural domains which are: decisions about agricultural production; access to and decision-making power about productive resources; control of the use of income; leadership in the community; and time allocation.

Each dichotomous indicator measures whether an individual respondent has achieved adequacy based on the definitions shown in Table 12, with corresponding weights that ensure that each domain receives equal weight when the indicators are aggregated together. We operationalize the A-WEAI in two ways—by determining the woman's overall empowerment score using the six weighted indicators, after which a woman's level of empowerment is established with respect to each individual A-WEAI indicator.

The Five Domains of Empowerment (5DE) Index is constructed using the Alkire–Foster method [10]. The measure shows how many domains women are empowered. This method can distinguish between women who are disempowered in just one domain and those disempowered across several domains at the same time. The 5DE index is calculated according to the following formula:

$$5DE = 1 - M_o = H_e + H_d \times A_e \tag{1}$$

M_o is the disempowerment index, calculated as the product of the proportion of disempowered women (H_d) and the percentage of domains in which disempowered women do not have adequate achievements (A_e). H_e is the percentage of empowered women, where empowered means that a woman has adequate achievements in four of the five domains or is empowered in a combination

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of the weighted indicators that make up at least 80 percent of the total. H_d is the percentage of disempowered women $(1 - H_e)$; A_e is the average absolute empowerment score among the dis-empowered; Hence, the 5DE index yields a value between 0 and 1, where higher values indicate greater empowerment.

Following Alkire et al. [9] and Gupta et al. [28], Gender Parity Index (GPI) compares the 5DE profile of the primary female in a household with that of the primary male. Typically, the primary female and a primary male will be husband and wife; however, where this is not the case, men and women in the same household were also classified as the primary male and female decision-makers regardless of their relationship to each other. Similarly, the most influential adult male and female in the household with respect to decision *vis-à-vis* agricultural production, access to productive resources; control of the use of income; leadership in the community; and time allocation can also be categorized as primary male and primary female.

Households without a primary adult male are excluded from the computation of the GPI. The GPI shows the share of women who are as empowered as their male counterparts. For those pairs where there is a disparity, the GPI shows the relative empowerment gap between the woman's 5DE score and the man's. The GPI is calculated according to the following formula:

$$\text{GPI} = 1 - (H_{\text{GPI}} \times I_{\text{GPI}}) \tag{2}$$

H_{GPI} is the percentage of households without gender parity; I_{GPI} is the average empowerment gap between women and men living in households that lack gender parity; Women's Empowerment in Agriculture Index (WEAI) methodology gives a weight of 90% to the 5DE Index and a weight of 10% to the GPI. Thus, the WEAI is computed as follows:

$$\text{WEAI} = (5DE \times 0.9) + (GPI \times 0.1) \tag{3}$$

Measurement of Land Tenure and Property Rights
LTPRs of farmers were measured using two key indicators—tenure type and tenure security.

Tenure type
This refers to the mode of land acquisition, which was categorised into four—inherited, Purchased, Leasehold, and Communal. These were included in the study models as the proportion of the farmlands cultivated by all members of the households that fall under each of the four categories.

Tenure security (legal)
A tenure is *de jure* secure, if it is duly registered with the land registry and/or the holder is issued a certificate of occupancy by the Governor of the State where it is located. Hence, this study focused on *de jure* with a view to examining the importance of title registration, which was captured in the model as the proportion of household's farmland to which the household holds the registered title.

Analytical methods
Poisson regression is used to model count variables, such as the household food security scores and household dietary diversity scores, but in a case when there is an over-abundance of zero counts in data than a Poisson would predict, the Zero-Inflated Poisson (ZIP) regression will be the appropriate model. We, therefore, used the two frameworks in this study of household food security among the farming households in Nigeria.

Poisson model
Poisson distribution is a discrete probability distribution for count variables and can be used to model how likely it is that an event will happen within a specified period of time. In this study, Poisson regression estimates how the explanatory variables influence the number of times the outcome variables occurred. The outcome variables here refer to the USDA HFS scores and HDDS. It is important to note that one of the basic assumptions of the Poisson model is that the expected value (mean) of the Poisson distribution is equal to its variance.

Following Cameron and Trivedi [12] and Greene [27], the Poisson regression model assumes that the dependent variable y given the vector of predictor variables **x** has a Poisson distribution (Eq. 4):

$$f(y_i|x_i) = \frac{e^{-\mu i}\mu_i^{yi}}{y_i!}, \ yi = 0, 1, 2, \dots \tag{4}$$

Greene [27] and Wooldridge [61] show that the mean and the variance of the Poisson distribution is given in Eq. 5 to be:

$$E[y_i|x_i] = \text{Var}[y_i|x_i] = \mu_i = \exp(x_i'\beta) \quad \text{for } i = 1, 2, \dots, n \tag{5}$$

The log-linear conditional mean function $E[y_i|x_i] = \mu_i$ and its equidispersion $\text{Var}[y_i|x_i] = \mu_i$ assumptions are the main features of the Poisson regression model.

Zero-Inflated Poisson Model
The Zero-Inflated Poisson (ZIP) is an extension of the Poisson regression model that is appropriate in a situation when the count data comprise many zero values than

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a Poisson distribution would predict [12]. Hence, ZIP models allow for two regimes—the outcome is always a zero count (regime I) and the counts follow a standard Poisson process (regime II). The ZIP models assume that the excess zero counts come from a logit or probit model and the remaining counts come from a Poisson model. Fitting a ZIP model in Stata allows for the specification of two separate models simultaneously: count model and the inflate model that predicts the always zero cases.

Assuming there are two possible scenarios for each respondent—the count is always zero (scenario I) and the counts (non-negative integers) are generated according to a Poisson model (scenario II). Suppose that the probability of having scenario I occurring is π, while the probability that scenario II occurs is $1 - \pi$. Hence, the probability distribution of the ZIP random variable y_i can be specified in Eq. 6 as:

$$\Pr(y_i = j) = \begin{cases} \pi_i + (1 - \pi_i)\exp(-\mu_i) & \text{if } j = 0 \\ (1 - \pi_i)\dfrac{\mu_i^{y_i}\exp(-\mu_i)}{y_i!} & \text{if } j > 0 \end{cases} \quad (6)$$

where j is the observed count, which is a non-negative integer; μ_i is from the Poisson component of the model, which can include an exposure time t and a set of k regressors (the X's), and is defined as follows:

$$\mu_i = \exp(\ln(t_i) + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki}) \quad (7)$$

The regression coefficients β_1, β_2, ..., β_k are unknown parameters that are estimated from a set of data.

This study, therefore, deployed the ZIP regression framework to analyse HFS among smallholder farmers in Nigeria. The results were also compared with those of traditional Poisson and Instrumental Variable Poisson in search of appropriate specification and endogeneity test. Table 1 shows the outcome variables of interest as well as the sets of regressors used in the study. It is worthy to note that the same set of regressors was used for both the Logit and the Poisson section of ZIP. Also, considering the fact that all the households responded to questions contextualised over the past 12 months of visiting each of the respondents makes the exposure time (t) not to be applicable to this study.

It is pertinent to note that the whole dataset for the HFS data had 81 households with no children with $0 \leq \text{HFS Score} \leq 10$ and 886 households with at least one (1) child, with $0 \leq \text{HFS Score} \leq 18$. Knowing full well that HFS scores for the two categories of households represent different levels of food insecurity (Table 11), relatively fewer cases of households with no children were dropped and the final analysis was based on the remaining 886 households with children. We must also note that the HDDS data were analysed within the framework of the Poisson regression because the score is a count variable ranging from 1 to 12.

Results and discussion

Socio-economic profiles of households of the maize and rice farmers

The socio-economic profiles of the sampled farm households are summarised in Table 2, while Table 3 summarises the characteristics of the farmlands cultivated by their members. As shown in Table 2, the majority (61.4%) of the farmers across the six geopolitical zones of Nigeria were within the age bracket of 31–50 years. The mean age was 46 years. This suggests that maize and rice farmers in Nigeria are mostly within the mid-age, and are relatively younger than the typical farmer in the area, which Eze et al. [21] reported was 59 years old. This, however, is most likely because of the recent drive by the Federal Government of Nigeria to encourage the youths to embrace agriculture, targeting maize and rice among selected crops.

Results in Table 2 also show that the typical farmer is 89% likely to belong to a male-headed household, 98% likely to be married, and 63% likely to belong to a household whose members jointly cultivated no more than 2 hectares of land, which is 51% of the cases are fragmented into two or more parcels. Results in Table 3 further show that about 54.0% of the households across the six GPZs inherited their farmlands while about 16.0% purchased the land. Also, 19.0% of the parcels were leased while 11.0% were communal land, respectively. The proportion of parcels held on leasehold and a communal agreement was found to be extremely (8.0% and 3.0%, respectively) lower among farmers drawn from northwest and northeast. With respect to key rights held, the majority (71.0%–78.0%) of the farmers across the study area possessed rights to—restrict others from their farm, grow tree crops and develop their parcels further by investing in an irrigating scheme, for example, while the majority of the households perceived they enjoy secure tenure on the land, as most believed they could sell (67.4%) and/ or bequeath (64.0%) the land to their children. However, only a few of the landholding was registered either with the Local Government Authorities (5.0%) or the State authorities (3.0%). The general LTPRs patterns are similar across the six GPZs, except that incidences of leasehold are relatively higher (47.0%) in the Southwest and incidences of inherited landholding are relatively lower in the Southwest (30.0%).

Unweighted adequacy scores by dual households

The unweighted adequacy scores for the indicators that make up the five domains of empowerment by the primary male and female in the household are shown

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Table 1 Definitions of study variables and their descriptive statistics

Variables	Descriptive statistics			
	Min	Max	Mean	Std Dev.
Dependent variables				
Household dietary diversity score (number of food groups consumed)	1.00	12.00	6.39	2.53
Household food security score (number of affirmative responses)	0.00	18.00	6.93	5.48
Land tenure and property rights variables				
Cultivating maize only (1 if yes, 0 otherwise)	0.00	1.00	0.39	0.49
Farm size (Ha)	0.06	134.50	5.93	8.99
Lowland share of farmland	0.00	1.00	0.49	0.45
Simpson Index (land fragmentation)	0.00	0.96	0.25	0.28
Simpson Diversity Index (crop diversity)	0.00	0.67	0.12	0.16
Maize × farm size	0.00	120.00	2.48	7.23
Maize × lowland	0.00	1.00	0.09	0.25
Maize × SI	0.00	0.96	0.11	0.23
Maize × SDI	0.00	0.67	0.05	0.11
Purchased share of farmland	0.00	1.00	0.18	0.35
Leasehold share of farmland	0.00	1.00	0.19	0.37
Communal share of farmland	0.00	1.00	0.10	0.28
Registered × freehold share	0.00	1.00	0.09	0.24
Credit amount	0.00	1,800,000	97,783.72	557,487.40
Empowerment variables				
Female achievement in asset	0.00	1.00	0.53	0.50
Female achievement in group membership (1 if yes, 0 otherwise)	0.00	1.00	0.60	0.49
Female achievement in productive decision (1 if yes, 0 otherwise)	0.00	1.00	0.63	0.48
Female achievement over control of income (1 if yes, 0 otherwise)	0.00	1.00	0.48	0.50
Female achievement in credit (1 if yes, 0 otherwise)	0.00	1.00	0.16	0.37
Female achievement in workload (1 if yes, 0 otherwise)	0.00	1.00	0.76	0.43
Parity (parity = 1)	0.00	1.00	0.32	0.47
Other controls				
Extension contact (at least once = 1; none = 0)	0.00	1.00	0.69	0.46
Age of head (years)	18.00	85.00	46.01	11.57
Age squared	324.00	7225.00	2252.24	1131.14
Education of head (schooling years)	0.00	18.00	7.81	5.85
Gender of head (female = 1, male = 0)	0.00	1.00	0.07	0.25
Head is single (1 if yes, 0 otherwise)	0.00	1.00	0.01	0.10
Head is widowed/divorced (1 if yes, 0 otherwise)	0.00	1.00	0.01	0.11
Head works off-farm (1 if yes, 0 otherwise)	0.00	1.00	0.59	0.49
Household size (number of people)	1.00	42.00	9.51	5.90
Dependent ratio	0.00	17.00	1.61	1.71
Location is North central (1 if yes, 0 otherwise)	0.00	1.00	0.17	0.37
Location is Northeast (1 if yes, 0 otherwise)	0.00	1.00	0.08	0.27
Location is Southeast (1 if yes, 0 otherwise)	0.00	1.00	0.09	0.29
Location is South-south (1 if yes, 0 otherwise)	0.00	1.00	0.08	0.28
Location is South west (1 if yes, 0 otherwise)	0.00	1.00	0.18	0.39

in Table 4. A value of one indicates complete adequacy and a value of zero indicates complete inadequacy in an indicator. Alkire et al. [9] define an individual as empowered if he or she achieves adequacy in 80% or more of the weighted indicators. Female adults in households where an adult male is present are inadequate in all the indicators compared to their male counterparts in the same household. However, they

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Table 2 Socio-economic characteristics of the maize and rice farming households. Source: Field Survey, 2017

| GPZ | NC | NE | NW | SE | SS | SW | All |
Variables	%	%	%	%	%	%	%
Age group							
At most 30	15.9	11.8	10.5	3.1	9.1	4.1	9.5
31–40	29.6	29.4	25.0	24.7	35.2	23.0	26.6
41–50	31.8	32.9	34.3	42.3	29.6	37.8	34.8
51–60	14.8	17.7	22.1	16.5	17.1	25.0	20.2
Above 60	8.0	8.2	8.1	13.4	9.1	10.2	9.0
Mean age (years)	44	45	46	48	45	48	46
Gender							
Male	89.2	97.7	97.1	96.9	86.4	88.3	93.3
Female	10.8	2.4	2.9	3.1	13.6	11.7	6.7
Marital status							
Married	98.3	96.5	98.1	96.9	96.6	98.0	97.7
Single	0.6	2.4	1.2	3.1	0.0	0.0	1.0
Widow/divorced	1.1	1.2	0.7	0.0	3.4	2.0	1.2
Education attainment							
No formal education	30.1	23.5	33.6	13.4	25.0	10.7	25.4
Arabic education	4.0	0.0	14.8	1.0	0.0	0.0	6.6
Primary education	18.8	14.1	16.2	35.1	21.6	26.0	20.4
Secondary education	25.6	21.2	15.2	21.7	33.0	41.8	24.4
Tertiary education	21.6	41.2	20.2	28.9	20.5	21.4	23.2
Mean education attainment (years)	8	9	6	9	8	10	8
Household size							
1–5	17.1	28.2	15.0	39.2	31.8	38.8	24.4
6–10	43.2	49.4	35.5	38.1	44.3	51.5	41.8
11–15	21.0	11.8	27.6	17.5	21.6	8.2	20.2
Above 15	18.8	10.6	21.9	5.2	2.3	1.5	13.6
Mean household size	11	9	11	7	7	7	10
Farm size (ha)							
Large farm (> 5Ha)	5.1	9.4	8.3	11.3	12.5	15.3	9.8
Medium farm (2–5 Ha)	25.6	30.6	26.2	28.9	22.7	30.6	27.2
Small farm (< 2Ha)	69.3	60.0	65.5	59.8	64.8	54.1	63.0
Mean farm size (ha)	2.2	2.3	2.2	2.2	2.5	3.0	2.4
Simpson Index							
Fragmented	47.7	49.4	43.3	40.2	47.7	64.8	48.6
Consolidated	52.3	50.6	56.7	59.8	52.3	35.2	51.4
Mean Simpson Index	52.0	51.0	57.0	60.0	52.0	35.0	51.0

NC North central, *NE* Northeast, *NW* Northwest, *SE* Southeast, *SS* South-South, *SW* Southwest

are more adequate in workload compared to males. Table 4 further shows that the primary males were more empowered in three out of the five domains of empowerment when compared to their female counterparts. We see that women are less adequate because they score particularly poorly in the production and income domains. As shown in Table 4, primary females in households are the least empowered, achieving adequacy in only 57% of the weighted indicators on average. This result is much higher when compared to the findings of Wouterse [62] who found that females in the household achieved adequacy in only 44% of the weighted indicators on average. Following Alkire et al. [9] cut-off, we find that in our study data—in dual households—22.53% of women are considered empowered against 52.76% of men, hence, the need to embrace policies targeted at improving women's access to productive resources.

Table 3 Distribution of cultivated parcels by tenure types. Source: Field Survey; 2017

Geopolitical zones	NC	NE	NW	SE	SS	SW	All
Acquisition mode %							
Inherited	62.0	70.0	60.0	54.0	55.0	30.0	54.0
Purchased	10.0	15.0	23.0	14.0	12.0	10.0	16.0
Leasehold	15.0	12.0	8.0	15.0	23.0	47.0	19.0
Communal	13.0	3.0	8.0	17.0	11.0	13.0	11.0
Rights held on farmland (%)							
Can grow tree crops	83.0	88.0	88.0	74.0	76.0	51.0	78.0
Can restrict access to others	74.0	85.0	83.0	72.0	71.0	43.0	71.0
Can develop structures on land	77.0	86.0	86.0	73.0	73.0	47.0	74.0
Can lease out to others	73.0	85.0	86.0	71.0	73.0	44.0	72.0
Can sell the land	65.0	83.0	82.0	67.0	64.0	38.0	67.0
Can bequeath to own children	63.0	82.0	78.0	60.0	63.0	36.0	64.0
Land titling status %							
Has well defined boundaries	25.0	22.0	15.0	3.0	12.0	23.0	18.0
Registered with traditional council	14.0	6.0	9.0	4.0	2.0	4.0	8.0
Registered with local government	5.0	14.0	5.0	0.0	1.0	5.0	5.0
Registered with the state	4.0	3.0	3.0	0.0	3.0	5.0	3.0

NC North central, *NE* Northeast, *NW* Northwest, *SE* Southeast, *SS* South-South, *SW* Southwest

Table 4 Adequacy scores by dual households. Source: Field Survey; 2017

Five domains of empowerment	Male Mean (SEM)	Female Mean (SEM)	Total Mean (SEM)
Production			
Asset ownership	0.89 (0.009)	0.53 (0.015)	0.96 (0.006)
Access to and decision on credit	0.35 (0.015)	0.16 (0.011)	0.40 (0.015)
Leadership			
Group membership	0.89 (0.010)	0.60 (0.015)	0.89 (0.009)
Resources			
Input in productive decisions	0.84 (0.011)	0.63 (0.015)	0.84 (0.011)
Income			
Control over use of income	0.79 (0.012)	0.48 (0.015)	0.87 (0.010)
Time allocation			
Workload	0.69 (0.014)	0.76 (0.013)	0.88 (0.010)
Empowerment (5 DE index)	0.77 (0.006)	0.57 (0.007)	0.81 (0.005)

Standard error of mean (SEM) in parenthesis

Fig. 2 Distribution of farming households by HFS Scores

Household food security status in Nigeria

The distribution of the farming households by HFS Scores is shown in Fig. 2 while Table 5 presents the distribution by geopolitical zone and food security status. About 16.82% of the households recorded zero HFS score Fig. 2, while 57.9% of the farming households were of either high or marginal food security status Table 5.

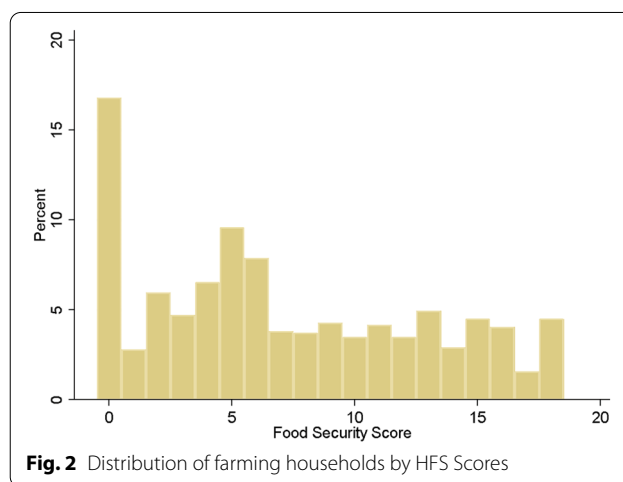The result in Table 5 is a confirmation that food insecurity remains a major challenge in Nigeria, with the prevalence of low and very low food security being much higher in the Northeast (60.3%) and the Southeast (54.7%) followed by the North central (45.7%) and South-South (40.2%) than the average (42.2%). A chi-square test of association in Table 5 affirms that the distribution of household food security status varies significantly at 1% level across all the geopolitical zones.

Diagnostic result—Hausman specification tests

Results in Tables 6 and 7 present the Hausman specification tests and that of endogeneity test (with land titling, off-farm activities, credit, and share of farmland that is purchased versus the traditional Poisson)

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Table 5 Classification of households by geopolitical zone and food security status. Source: Field Survey; 2017

Food Security Status	NW	NC	NE	SW	SS	SE	Total
High food security	93 (28.5)	40 (25.0)	11 (15.1)	54 (35.1)	13 (16.9)	9 (12.2)	220 (25.5)
Marginal food security	112 (34.4)	47 (29.4)	18 (24.7)	45 (29.2)	33 (42.9)	25 (33.8)	280 (32.4)
Very low food security	67 (20.6)	39 (24.4)	28 (38.4)	25 (16.2)	10 (12.9)	26 (35.1)	195 (22.6)
Low food security	54 (16.6)	34 (21.3)	16 (21.9)	30 (19.5)	21 (27.3)	14 (18.9)	169 (19.6)
Total	326 (100.0)	160 (100.0)	73 (100.0)	154 (100.0)	77 (100.0)	74 (100.0)	864 (100.0)

Pearson Chi^2 (df = 9) = 46.78 Prob. = 0.000

NC North central, *NE* Northeast, *NW* Northwest, *SE* Southeast, *SS* South-South, *SW* Southwest

Table 6 Diagnostics for USDA Household Food Security. Source: Field survey; 2017

Test Description for USDA HFS	Chi sq	df	*p*-value	Comment
Endogeneity test (IVP with Freehold × right registered vs Poisson)	4.80	36	1.000	Rejected
Endogeneity test (IVP with Off-farm activities vs Poisson)	10.16	36	1.000	Rejected
Endogeneity test (IVP with Credit vs Poisson)	184.88	36	0.000	Accepted
Endogeneity test (IVP with Purchased vs Poisson)	15.01	36	0.998	Rejected
IIA test (ZIP vs Poisson)	2509.74	36	0.000	Accepted
Endogeneity test (IVP with Freehold × right registered vs Poisson without credit)	4.55	35	1.000	Rejected
Endogeneity test (IVP with Off-farm activities vs Poisson without credit)	19.72	35	0.9759	Rejected
Endogeneity test (IVP with Purchased vs Poisson without credit)	20.80	35	0.9631	Rejected
IIA test (ZIP vs Poisson without credit)	2852.21	35	0.000	Accepted

Table 7 Diagnostics for household dietary diversity score. Source: Field survey; 2017

Test Description for HDDS	Chi sq	df	*p*-value	Comment
Endogeneity test (IVP with Freehold × right registered vs Poisson)	5.45	36	1.000	Rejected
Endogeneity test (IVP with Off-farm activities vs Poisson)	7.96	36	1.000	Rejected

and Independence of Irrelevant Alternatives (IIA) test (ZIP versus Poisson) for both USDA HFS and HDDS. Considering the USDA HFS, the calculated Chi-square value associated with the Hausman endogeneity test carried out with respect to the amount of credit obtained was significant at 1%, indicating that the difference in coefficients of the IV Poisson and the traditional Poisson model is systematic. Hence, there is enough evidence to suggest that the credit variable is endogenous to the HFS model. Similarly, the calculated Chi-square value associated with the Hausman endogeneity tests with respect to land titling, off-farm activities, and share of farmland on the purchase was not statistically significant even at the 10% level. This shows that the difference in coefficients of the IV Poisson and the traditional Poisson models is not systematic. Hence, we reject the hypothesis that land titling, participation in off-farm activities, and share of farmland on purchase are endogenous to the household food security models. The endogeneity nature of credit in the USDA HFS model made us run two Poisson regression models—Poisson with and without credit. The results with respect to the logit part of the ZIP, however, revealed that the difference in coefficients of the traditional Poisson and the Poisson part of the ZIP model is systematic at the 1% level. Hence, considering these study data, ZIP is the most appropriate specification of the USDA household food security problem.

It is pertinent to note from Table 7 that the IIA test is not applicable to our HDDS model. Also, the calculated Chi-square value associated with the Hausman endogeneity tests with respect to land titling and off-farm activities were not significantly different from zero. This shows that the difference in coefficients of the IV Poisson and the traditional Poisson models is not systematic. Hence, we reject the null hypothesis that those variables are endogenous to the HDDS model. We, however, did not find any sufficient basis to conclude that the Hausman endogeneity test with respect to credit and share of farmland on purchase are endogenous to the HDDS model.

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Determinants of household food security

Tables 8 and 9 present the main econometric results in this study. The results include estimates of the traditional Poisson model (with and without credit), the Instrumental Variable (IV) Poisson model, and the Zero-Inflated Poisson (ZIP) model, including the count (Poisson part) and the logit "certain zero" (Inflate) component. The parameters of both the traditional Poisson and ZIP models were computed using the maximum likelihood estimation (MLE) method, while the IV-Poisson model was estimated by the generalized methods of moments (GMM). The likelihood ratio tests showed that the two MLE versions provide a good fit to the data, as the calculated chi-square values associated with the two versions of the model were both significant at $p < 0.01$.

The evidence-based results in Tables 8 and 9 are generally consistent, particularly in terms of signs of most parameters, across the three specifications: Poisson, IV Poisson, and ZIP model. Across the Poisson and ZIP specifications, 20 variables out of 35 are statistically significant with 11 and seven being significant at 1% level, respectively, while only three variables are statistically significant under the IV Poisson specification. If land titling and working off-farm were to be endogenous, however, the IV Poisson results would suggest that the influence of all the land and LTPR-related variables were insignificant, even though they generally share similar signs with those of the traditional Poisson and ZIP specifications. With the evidence to support the endogenous credit amount given the study data, we consider evidence-based on IV Poisson model, ZIP without credit, and Poisson (HDDS) to be efficient and consistent, and thus robust for policy analysis.

Determinants of "certain zero" (no food insecurity)

The ZIP inflates regression result provides evidence with respect to the influence of the hypothesised food security determinants on the likelihood of the USDA HFS score being certainly zero. This implies that a household will not give any positive response to any of the 18-food insecurity USDA questions, thus indicating that such households are surely food-secure in all regards. As shown in columns 9 and 10 of Tables 8 and 9, only three of the hypothesised food security determinants were significantly different from zero. The variables include a share of farmland on the purchase, household head works off-farm and a dummy variable for Southeast.

The coefficient of share of farmland on purchase is positive and significant at the 1% level. This shows that the higher the proportion of farmland on purchase the more likelihood of a household recording a "certain zero", and thus not experiencing any form of the food insecurity dimensions that underlie the USDA HFS assessment.

Similarly, the likelihood of recording a "certain zero" is significantly ($p < 0.10$) higher among household heads that participate in off-farm activities. These suggest, *ceteris paribus*, that household heads working off-farm are most likely not to experience any form of food insecurity. On the contrary, a dummy variable for Southeast as the location is negative and significant at $p < 0.05$, this implies that households residing in Southeast are less likely to record a "certain zero", and hence, less likely to experience any form of food insecurity when compared to the reference category (Northwest).

LTPRs and severity of household food insecurity

The IV Poisson and ZIP—Count (Poisson part) of the estimated ZIP model provide evidence with respect to the influence of various hypothesised determinants on the severity of household food insecurity. Results in relation to the influence of land and LTPR-related variables—farm size, land fragmentation, crop diversity and the share of farmland on purchase, lease, and communal, registered and lowland area in the farmland are found in the first 13 rows of Table 8. One and four out of the 13 land and LTPR-related variables were associated with significant coefficients in the IV Poisson and ZIP count (severity of food insecurity) model, respectively. Across the two models, the coefficient of the farm size was positive and significant at 5% level. This shows that increase in farm size results in the severity of food insecurity, this, however, does not follow a priori expectation. The likely explanation is that in an area where the farm households depend on marginal agricultural land and the numerical increase in the economically active members of a household cannot be matched with the existing food supply, such households will ultimately end up with food insecurity.

On the contrary, the coefficient of the crop diversity, households that cultivate maize only, and share of farmland on purchase were all negative and significant at 1% and 10% levels, respectively. These show that the severity of food insecurity among the farm households declines with an increase in crop diversity and share of farmlands acquired through direct purchase as against the cultivation of communal land. This result agrees with the findings of Shittu et al. [52], who found that only smallholder farmers that were de facto secure will embrace climate-smart agricultural practices. It also supports the evidence from Roth and McCarthy [49] who opined that secure land tenure provides incentives for farmers to ensure full utilization of their land.

The evidence with respect to crop diversity implies that households with higher crop diversity intensity reduce the severity of food insecurity. This is feasible with the appropriate management of the price and production

Table 8 Estimated Poisson and ZIP Models of Household Food Security in Nigeria

Explanatory variables	USDA household food security										HDDS	
	Poisson 1		IV Poisson		Poisson 2		ZIP Count*		ZIP Inflate		Poisson	
	Coef	z	Coef	z	Coef	z	Coef	z	Coef	z	Coef	z
Maize	− 0.076	− 1.45	− 0.239	− 0.92	− 0.074	− 1.42	− 0.003	− 0.05	0.515	1.27	− 0.012	− 0.22
Farm size (Ha)	0.004**	2.48	0.011***	2.25	0.004**	2.49	0.004**	2.57	0.006	0.43	0.000	0.17
Lowland share of farmland	− 0.095**	− 2.41	− 0.207	− 1.33	− 0.095**	− 2.39	− 0.019	− 0.47	0.516	1.58	− 0.057	− 1.45
Simpson Index (land fragmentation)	0.048	0.76	0.036	0.15	0.049	0.77	− 0.050	− 0.78	− 0.599	− 1.20	0.047	0.76
Simpson Diversity Index (crop diversity)	− 0.243**	− 2.36	− 0.380	− 0.87	− 0.246**	− 2.38	− 0.180*	− 1.73	0.515	0.66	0.113	1.13
Maize × farm size	− 0.014***	− 4.19	− 0.035	− 1.31	− 0.014***	− 4.23	− 0.012***	− 3.56	0.003	0.13	0.001	0.17
Maize × lowland	0.042	0.60	0.308	0.71	0.043	0.61	− 0.017	− 0.24	− 0.515	− 1.00	0.052	0.77
Maize × SI	0.101	1.00	0.407	0.56	0.096	0.96	0.127	1.27	0.362	0.50	− 0.017	− 0.18
Maize × SDI	0.275*	1.69	0.553	0.63	0.268	1.65	0.213	1.31	− 0.379	− 0.33	− 0.154	− 0.97
Share of farmland on purchase	− 0.228***	− 5.50	− 0.185	− 0.71	− 0.232***	− 5.61	− 0.074*	− 1.77	0.831***	3.18	− 0.068*	− 1.74
Leasehold share of farmland	− 0.013	− 0.33	0.039	0.25	− 0.013	− 0.32	− 0.039	− 0.98	− 0.148	− 0.47	0.047	1.27
Communal share of farmland	− 0.037	− 0.77	0.150	0.51	− 0.039	− 0.82	− 0.036	− 0.75	0.103	0.29	0.016	0.35
Registered × freehold share	− 0.012	− 0.23	− 0.018	− 0.06	− 0.012	− 0.22	− 0.030	− 0.55	− 0.130	− 0.31	0.056	1.10
Credit amount	− 4.4E− 08	− 1.28	− 0.002	− 0.02				−	−	−	1.7E− 08	0.86
Female achievement in asset	− 0.004	− 0.12	0.012	0.10	− 0.002	− 0.07	− 0.006	− 0.21	0.021	0.09	0.052*	1.84
Female achiev. group membership	− 0.103***	− 3.24	0.082	0.56	− 0.105***	− 3.29	− 0.081**	− 2.56	0.161	0.67	0.058*	1.89
Female achiev. productive decisions	0.048	1.59	0.038	0.19	0.05	1.64	0.052*	1.70	− 0.032	− 0.14	0.003	0.12
Female achiev. over control of income	− 0.075**	− 2.45	− 0.015	− 0.11	− 0.075**	− 2.44	− 0.116***	− 3.74	− 0.233	− 0.99	0.031	1.06
Female achievement in credit	0.071**	2.04	1.658***	4.35	0.068*	1.96	0.075**	2.18	0.093	0.37	0.019	0.56
Female achievement in workload	− 0.058*	− 1.83	0.126	0.58	− 0.059*	− 1.88	− 0.058*	− 1.84	0.002	0.01	0.054*	1.69
Parity (Parity=1)	0.115***	3.16	− 0.583***	− 3.34	0.118***	3.25	0.181***	4.93	0.389	1.42	− 0.064*	− 1.81

+ *Instrumented:* Credit Amount; *Instruments:* FreeholdRightReg Offfarmincome Maize Farmsize_Ha LowLand SI SDI MaizeFarmSize MaizeLowLand MaizeSI

Poisson 1: Poisson with credit; MaizeSDI Purchased Leased_rented Communal FemAchmtAsset FemAchmtGrpMem FemAchmtProDec

Poisson 2: Poisson without credit; FemAchmtIncCon FemAchmtCredit FemAchmtWork Parity_dummy Extensioncontact Age AgeSq SchlgYr

ZIP Count*: ZIP Count without credit. Gender Never_married Ever_married HHSize DepRatio NC NE SS SW Native PHCN CoopSociety

***, **, * represent statistical significance at 1%, 5% & 10%

Table 9 Estimated Poisson and ZIP model of household food security in Nigeria

Explanatory variables	USDA household food security										HDDS	
	Poisson 1		IV Poisson		Poisson 2		ZIP Count*		ZIP Inflate		Poisson	
	Coef	z	Coef	z	Coef	z	Coef	z	Coef	z	Coef	z
Extension contact (access = 1)	− 0.083***	− 2.92	− 0.305***	− 2.79	− 0.084***	− 2.94	− 0.103***	− 3.57	− 0.138	− 0.65	− 5.90E−05	0.00
Age of head	0.013*	1.90	− 0.008	− 0.09	0.013*	1.89	0.003	0.37	− 0.065	− 1.36	0.001	0.10
Age squared	− 8.30E−05	− 1.22	0.000	0.16	− 8.2E−05	− 1.21	2.31E−05	0.33	0.001	1.35	− 1.70E−05	− 0.24
Education of head (schooling years)	− 0.001	− 0.27	− 0.009	− 0.59	− 0.001	− 0.26	0.001	0.40	0.011	0.63	0.006***	2.73
Gender of head (female = 1)	− 0.061	− 1.03	0.207	0.32	− 0.060	− 1.00	0.068	1.14	0.526	1.41	0.035	0.63
Head is single	0.267**	2.31	− 0.285	− 0.31	0.269**	2.32	0.220*	1.88	− 0.394	− 0.35	− 0.209	− 1.43
Head is widowed/divorced	− 0.426***	− 2.80	− 0.471	− 0.56	− 0.425***	− 2.79	− 0.416***	− 2.70	0.101	0.13	0.001	0.01
Head works off-farm	− 2.37E−07***	− 4.47	− 2.10E−07	− 0.89	− 2.41E−07***	− 4.55	− 1.01E−07**	− 1.97	4.69E−07*	1.86	− 3.40E−09	− 0.08
Household size	− 0.001	− 0.04	− 0.001	− 0.09	− 0.001	− 0.06	− 0.001	− 0.37	− 0.004	− 0.22	0.002	0.79
Dependent ratio	− 0.007	− 0.91	− 0.032	− 0.44	− 0.007	− 0.93	− 0.002	− 0.23	0.040	0.71	− 0.020**	− 2.44
North central dummy	0.098***	2.46	0.199	0.85	0.095**	2.39	0.090**	2.25	0.019	0.07	0.026	0.65
Northeast dummy	0.312***	6.55	0.404**	2.08	0.312***	6.55	0.255***	5.29	− 0.350	− 0.84	− 0.403***	− 6.79
Southeast dummy	0.272***	5.43	0.216	1.17	0.271***	5.41	0.127**	2.52	− 1.114**	− 2.14	− 0.309***	− 5.48
South-south dummy	− 0.005	− 0.10	− 0.3148	− 1.18	− 0.006	− 0.12	− 0.094*	− 1.77	− 0.611	− 1.45	− 0.007	− 0.14
South west dummy	− 0.144***	− 2.97	0.1574	0.75	− 0.1512***	− 3.12	− 0.1122**	− 2.32	0.249	0.77	0.167***	3.97
Constant	1.8***	10.38	2.7814	1.15	1.8035***	10.40	2.1319***	12.07	− 0.815	− 0.67	1.736***	10.30
LR Chi sq. (36)	295.49				293.58		192.87				241.06	
Log likelihood	− 3446.63				− 3447.58		− 2733.12				− 232.36	

+ *Instrumented*: Credit Amount; *Instruments*: FreeholdRightReg Offfarmincome Maize Farmsize Farmsize_Ha LowLand SI SDI MaizeFarmSize MaizeLowLand MaizeSI

Poisson 1: Poisson with credit; MaizeSDI Purchased Leased_rented Communal FemAchmtAsset FemAchmtGrpMem FemAchmtProDec

Poisson 2: Poisson without credit; FemAchmtIncCon FemAchmtCredit FemAchmtWork Parity_dummy Extensioncontact Age AgeSq SchlgYr

ZIP Count*: ZIP Count without credit. Gender Never_married Ever_married HHSize DepRatio NC NE SE SS SW Native PHCN CoopSociety

***, **, * represent statistical significance at 1%, 5% & 10%

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risks by the farmers, which in turn ensures more food options for the household and income through market participation from the surpluses. This result agrees with the findings of Adjimoti and Kwadzo [1] and Mango et al. [38] who found that households that are into crop diversification have a greater tendency to be food-secure particularly those growing cereals, as well as, root and tuber crops. Results in Table 8 show that the extent of food insecurity reduces with the cultivation of only maize on the farmland, this can be explained by the fact that the farmers can plant two to three rounds of arable crops in a successive manner before the year runs out, hence, getting more income to cushion the effect of food insecurity.

Women's empowerment and severity of household food insecurity

The IV Poisson and ZIP—Count (Poisson part) of the estimated ZIP model provide evidence with respect to the influence of various women's empowerment-related variables on the severity of household food insecurity. Results in relation to the influence of women's empowerment characteristics—gender parity and female achievement in the asset, group membership, productive decisions, income control, credit, and workload are found in Table 8. Two and Six out of the seven women's empowerment variables were statistically significant in the IV Poisson and ZIP count (severity of food insecurity) models, respectively.

The evidence in respect to female achievement in group membership, income control, and workload shows that the coefficients of these variables are significantly negative at 1%, 5%, and 10% levels, respectively. These indicate that the achievement of females in group membership, income control, and workload reduces the extent of food insecurity among the farming households in Nigeria. The result agrees with the findings of Sraboni et al. [56] and Tanankem et al. [58] who found that increases in women's empowerment are positively linked with calorie availability and dietary diversity at the household level.

On the contrary, the results in Table 8 further reveal that the female achievement in the productive decisions was not significant under IV Poisson but was significant and positive at the 10% level under ZIP. This result does not follow a priori expectation as it suggests that female achievement in productive decision increases the extent of food insecurity among the smallholder farmers in Nigeria. On the other hand, gender parity and female achievement in credit were negatively and positively significant at 1% levels, respectively, under IV Poisson. This shows that the extent of food insecurity among the farming households declines with gender parity and rises with female achievement in credit. This implies that the level of food insecurity reduces when women are equally empowered to the men in their households *vis-à-vis* 5DE, however, the pressure to pay the loan may put a strain on the women's ability to provide for home consumption, thereby impairing the household food security level. These findings, however, contradict that of Adjimoti and Kwadzo [1] who found that households that have access to credit are more likely to be food-secure than their counterparts without credit access.

Socio-demographic factors and severity of household food insecurity

The IV Poisson and ZIP—Count (Poisson part) of the estimated ZIP model provide evidence with respect to the influence of various socio-demographic variables on the severity of household food insecurity. Results in respect to the influence of socio-demographic characteristics—access to extension services, age, education, gender, a dummy variable for a household head that is single, off-farm activities, as well as dummies for north central, northeast, southeast, south-south, and southwest GPZs are found in Table 9. Two and Nine out of the 15 socio-demographic variables were associated with significant coefficients in the IV Poisson and ZIP count (severity of food insecurity) models, respectively.

The coefficient of access to extension contact was negative and significant at a 1% level across the two models. This shows that the extent of food insecurity among farming households declines with having access to extension services. This implies that access to extension services will give greater opportunity to farmers in having access to improved input and crop production techniques that will later translate into larger farm output. The result agrees with the findings of Kehinde et al. [33] who found that access to extension services is inversely related to severity of food insecurity.

However, the coefficient of the household head that is single is positive and significant at 10%. This shows that being a single household head will increase the extent of food insecurity among the farming household in the study area. The evidence with respect to household head that is widowed/divorced is significantly negative at a 1% level, though we expect this variable to be positive because the high dependency ratio is severe mainly on the head who are either widowed or unmarried.

The evidence with respect to the household head that works off-farm shows that the coefficient of the household head that works off-farm is significantly negative at the 5% level. This shows that the extent of food insecurity reduces when a household head participates in an off-farm activity, indicating that cash earnings from off-farm activities increase the households' ability to withstand the extent of food insecurity. Farming households are therefore encouraged to engage in multiple livelihood

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activities which will provide streams of income that enhance adequate food access, thus, increasing the food security status of the farmers.

The coefficient of the dummy variable for north central, northeast, and southeast GPZs is significant and positive at 1% and 5% levels, respectively (Table 9). This shows that the extent of food insecurity is location-specific as farm households residing in these three GPZs are liable to food insecurity as opposed to those farmers residing in the northwest GPZ. We, however, found that the coefficients of the south-south and southwest GPZs are negative and significant at 5% and 10% levels, implying that the severity of food insecurity reduces among the farming households residing in south-south and southwest geo-political zones.

Determinants of household dietary diversity

The Poisson model provides evidence with respect to the influence of various hypothesised determinants on household dietary diversity. Results in relation to the influence of land and LTPRs related variables, as well as, women's empowerment are found in Table 8 while that of the other socio-economic variables is presented in Table 9. The coefficients of 10 out of the 36 variables were statistically significant in the Poisson model.

The coefficient of the share of farmland on purchase is negative and significant at the 10% level. This suggests a reduction in the household dietary diversity which is against the a priori expectation. The possible explanation could be that the more the proportion of farmland purchased by the households, the more the incurred cost which invariably reduced the money available for food consumption among other things, hence, reducing the household access to diverse food. The evidence in respect of female achievement in the asset, group membership and workload shows that the coefficients of these variables are significant and positive at the 10% level. These indicate that the achievement of females in the asset, group membership and workload increase the dietary intake of diverse food groups among the farming households in Nigeria. This result agrees with the findings of Sraboni et al. [56] and Tanankem et al. [58] who found that increases in women's empowerment are positively linked with calorie availability and dietary diversity at the household level.

The coefficient of household head education is significantly positive at 1%. This shows that increase in the schooling years of household heads will increase household dietary diversity. This implies that the level of formal education has a positive impact on increasing the economic access of the households to diverse food. The result corroborates the findings of Ahmed et al. [3] who found that higher education translates to efficient use of

agricultural input and technology which results in higher yield and then more income.

Results in Table 8 shows that the coefficient of dependency ratio is significant and negative at a 5% level. This shows that the higher the number of dependents, the more people that are eating from the same resources, hence, the household members may not be able to take enough food when compared to the farming households with a smaller number of dependents. This implies that the availability of adequate adult labour can have a positive effect on access to diverse food groups while a household with a more dependency ratio compared to the economically active age group has less access to diverse food groups.

The results in Table 9 further reveal that the coefficients of the dummy variable for northeast and southeast GPZs are significant and negative at a 1% level. This shows that dietary diversity is location-specific as farm households residing in the two GPZs are less likely to have access to diverse food intake as opposed to their counterparts in the northwest GPZ. We, however, found that the coefficients of the southwest GPZ are positive and significant at a 1% level, implying that the household dietary diversity increases among the farm households residing in the southwest geo-political zone.

Conclusion and policy implications

This study supports the existing argument in the literature [7, 13, 20, 56] that women's empowerment and secure rights to land can directly contribute to the agricultural production of the farmer which can lead to an increase in farm income. Income gain can then result in physical and economic access to food which eventually improves household food security. However, the issue of farm size, female achievement in the productive decision, and access to credit can be subjected to further research as those variables increase the severity of food insecurity among the smallholder farmers.

Attempting to answer the research questions in this study leads us to these interesting findings. First, the ZIP inflate regression result shows that households that have a share of farmland on purchase and also participate in off-farm activities are likely to be certain food-secure in all regards. Conversely, IV Poisson and ZIP Count results show that increase in farm size results in the severity of food insecurity. Second, crop diversity, households that cultivate maize only, the share of farmland on purchase, and access to extension contact significantly reduce the severity of food insecurity while an increase in farm size increases the extent of food insecurity.

The evidence with respect to women's empowerment reveals that gender parity and female achievement in group membership, income control, as well as workload;

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reduce the severity of food insecurity among the farming households in Nigeria. We, however, discover that the female achievement in the productive decision and credit increases the severity of food insecurity among the smallholder farmers. Third, the analyses reveal that education of the household head, female achievement in the asset; group membership, and workload are the major factors that positively influenced household dietary diversity.

Arising from the abovementioned empirical findings, the paper concludes that adoption of climate-smart practices, such as improved agronomic practices, water management, tillage and residue management, integrated nutrient management, and agroforestry, will help both the maize and rice farmers to overcome the issue of marginal farmlands. Government and relevant agencies should intensify the promotion of crop and livelihood diversification among the smallholder farmers especially to those currently less diversified to improve their food security status. In the same vein, the extension agents should be adequately funded and trained for prospective professional attributes to allow for effective extension services delivery. Finally, policies targeted at improving women's access to productive resources should be put in place to enhance the household food security status in Nigeria.

Appendix

See Tables 10, 11, 12

Table 10 The 18-households food security questions as adapted. Source: USDA Guide (2000)

S/N	Questions/statements	N	S	O
1	We were worried our food would run out before we got money to buy more			
2	The food we bought just didn't last and we didn't have money to get more			
3	We couldn't afford to eat balanced diet			
4*	We relied on only a few kinds of low-cost food to feed the children			
5*	We couldn't feed the children a balanced meal			
6*	The children were not eating enough because we just couldn't afford enough food			
7	Did some adults ever have to eat less than you felt you should eat because there wasn't enough money to buy food?	Yes() No()		
8	How often did this happen in the last 12 months?			
9	Did some adults ever had to eat less than you felt you should eat because there wasn't enough money for food	Yes () No()		
10	Were some members ever hungry but didn't eat because you couldn't afford enough food?	Yes () No()		
11	Did some members ever lose weight within the last 12 months because there wasn't enough food?	Yes () No()		

Table 10 (continued)

S/N	Questions/statements	N	S	O
12	Were there ever a time within the last 12 months that some adults could not eat for a whole day because there wasn't enough money to buy food	Yes () No()		
13	How often did this happen in the last 12 months?			
14[*]	Did you ever have to cut the size of some of the children's meals within the last 12 months because there wasn't enough money to buy food?	Yes () No()		
15[*]	Did any of the children ever skip meals because there wasn't enough money for food within the last 12 months because there wasn't enough money to buy food?	Yes () No()		
16[*]	How often did this happen in the last 12 months?			
17[*]	In the last 12 months, were the children ever hungry but you just couldn't afford more food?	Yes () No()		
18[*]	In the last 12 months, did any of the children ever not eat for a whole day because there wasn't enough money for food?	Yes () No()		

N Never, *S* Sometimes, *O* Often

[*] Not applicable to households without children

Table 11 USDA food security classification

Status	Number of affirmative responses	
	Households with children	Households without children
High food security	0–2	0–2
Marginal food security	3–7	3–5
Low food security	8–12	6–8
Very low food security	13–18	9–10

USDA (2016)

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Table 12 Domains, Indicators and their respective weights in the A-WEAI. Source: Alkire et al

Domain	Indicator	Definition of Indicator	Weight
Production	Input in productive decisions	Sole or joint decision-making over food, farming, livestock and fisheries	1/5
Resources	Ownership of assets	Sole or joint ownership of major household assets	2/15
	Access to and decisions on credit	Access to and participation in decision-making concerning credit	1/15
Income	Control over use of income	Sole or joint control over income and expenditures	1/5
Leadership	Group membership	Whether respondent is an active member in a group	1/5
Time	Workload	Allocation of time to productive and domestic tasks	1/5

Authors' contributions
MOK took part in designing the questionnaire, data collection, data analysis and wrote the final manuscript. AMS is the principal investigator of the nationwide survey that produces this paper; he conceived the study and designed the questionnaire as well as participated in the writing of the final manuscript. AGA proofread the final manuscript. MGO participated in the data collection and the analysis. All authors read and approved the final manuscript.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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